National Aeronautics and Space Administration

NASA ADVANCED SUPERCOMPUTING (NAS) DIVISION

SCIENTIFIC VISUALIZATION

The NAS Division's data analysis and visualization team researches and applies advances in information systems technology to enhance the understanding of computational simulation and experimental data in support of NASA missions.

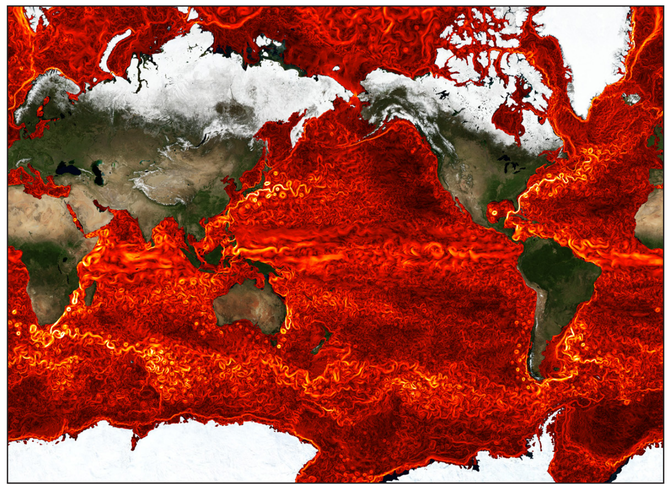
Benefit

NAS visualization experts develop and implement advanced software tools and technologies customized to help scientists and engineers gain insight into complex datasets and make new discoveries for agency missions. The team's extensive suite of tools and techniques includes both traditional post-processing visualization methods and a sophisticated concurrent visualization framework. Together with NAS's in-house developed hyperwall graphics and data analysis system, these tools allow users to explore high-resolution results in real time and pinpoint critical details in large scientific datasets.

Overview

To help users understand and interpret their results, these experts capture, process, and render enormous amounts of data to produce high-resolution images and videos. They also develop and adapt specialized visualization solutions for the agency's unique science and engineering problems. Working closely with users, the team continually customizes and creates new tools and techniques to expose the intricate temporal and spatial details of computational models.

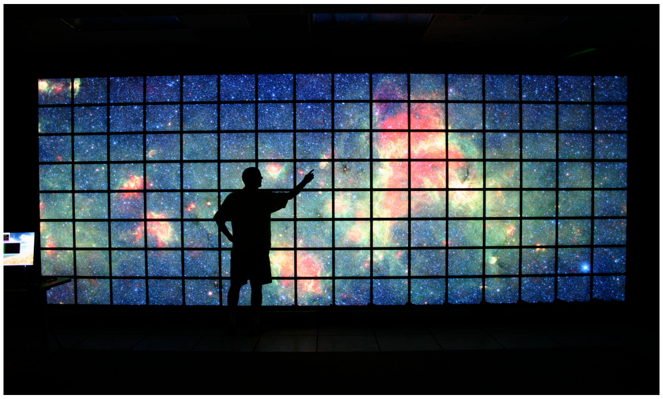
Recently, visualization team support helped earth scientists get a more accurate representation of the global sea-ice state than is currently available elsewhere. Collaborating with scientists working under the Estimating the Climate and Circulation of the Ocean 2 (ECCO2) project, the NAS team developed a series of custom tools and methods used to improve the visibility of cracks and deformations that develop as wind blows over sea ice, and created new high-resolution images and animations. This work will ultimately help ECCO2 scientists develop insights into how and why the global earth system is changing, and will improve our understanding of life-supporting planetary cycles.



Surface current speeds from a simulation with 1/16-degree horizontal grid spacing. The currents and associated 3D full ocean state can be used to drive applications such as improved estimates of carbon uptake by the oceans and improved melt-rate estimates for the Antarctic and Greenland ice sheets. (Chris Henze, NASA/Ames)

hyperwall

The NAS visualization team develops special technologies for moving large datasets directly to graphics hardware as they are generated so that the data can be displayed and analyzed in real time. A cornerstone of this capability is the hyperwall, one of the largest and most powerful visualization systems in the world. This system gives users a supercomputer-scale environment to handle the very large datasets produced by high-end computers and observational instruments. Recently upgraded to NVIDIA's powerful GeForce GTX 780 Ti graphics processing units (GPUs) and 2,560 Intel Xeon Ivy Bridge processor cores, the hyperwall has 57 teraflops of peak processing power and direct access to NAS's 2.9 petabytes of online disk storage, also used by the Pleiades supercomputer.



The quarter-billion pixel hyperwall graphics and data analysis system is a matrix of functionally interconnected graphics workstations and displays coupled directly to the NAS facility's Pleiades supercomputer via InfiniBand. The 128-screen, quarter-billion-pixel flat panel display system measures 23 feet wide by 10 feet high. (Sue Kim, NASA/Ames)

Concurrent Visualization

The hyperwall is integrated with the NAS-developed concurrent visualization framework, which enables real-time graphical processing and display of data while applications are running. This capability is critical to supporting huge datasets that are difficult to store, transfer, and view as a whole, and delivers results that are immediately available for analysis. Most importantly, concurrent visualization makes it feasible to render and store animations showing every simulation timestep, which allows users to see rapid processes in their models—often for the first time. With concurrent visualization users can also identify computational problems or optimize parameters on the fly. Live production data can be pulled from the supercomputer to the hyperwall without hindering code performance, allowing users to reap the benefits of visualization services without slowing turnaround time of their analyses.

A recent use of concurrent visualization involved creating high-temporal-resolution animations from a large-scale magnetohydrodynamics (MHD) code. In this case, the MHD solver timestep was determined by the fast dynamics of the magnetic field, yet the animations captured successive timesteps—allowing NAS visualization experts to track the fastest details of the magnetic field evolution, as well as the hydrodynamics. It would have been impracticable to do this by writing the timestep data to disk, since thousands of timesteps containing two vector quantities over a domain with 2 billion grid points were needed.

Cutting-Edge Visualization Technologies

NAS experts are also exploring other cutting-edge visualization capabilities, including efficient GPU techniques that allow users to perform computations in applications traditionally handled by central processing units (CPUs). Efficient GPU computation and rendering techniques enable both concurrent and rapid-iteration, post-processing visualizations. The visualization team also employs multivariate data visualization techniques and statistical analyses. Multivariate techniques include "linked derived spaces," which allows linking and selecting subsets of 2D scatterplots to facilitate visual tracking of key data points across all variables. Out-of-core data management techniques enable exploration of datasets that are too large to fit in memory.

In 2011, NAS added a compute cluster to Pleiades that features 64 dual-core Intel (Westmere) nodes, each with an NVIDIA Tesla M2090 GPU. This cluster, like all the other Westmere racks in the system, is fully integrated into Pleaide's InfiniBand fabric, but the nodes have more memory and direct-attached GPUs. This cluster allows Pleiades users to develop and deploy their GPU-accelerated codes in the same environment where they are running their traditional codes. The GPU-enabled nodes also provide a highly efficient platform for concurrent visualization, as it will be straightforward to transfer data to the GPU either directly from the host node, or across the InfiniBand fabric from another Pleiades node.

Background

Over the past several years, NAS experts have applied the capabilities described above to many applications, benefitting projects in all of the agency's key mission areas. Future advancements, such as streaming of visualizations to remote users and development of large GPU clusters, will expand the capacity and breadth of these valuable services. Over the next few years, scientific visualization will continue to become more tightly integrated into the traditional environment of supercomputing, storage, and networks to offer an even more powerful tool to scientists and engineers.

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For more information on our data analysis and visualization services, please visit: www.nas.nasa.gov/hecc/services/visualization_services.html

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